DEVELOPMENT OF THE DASHBOARD OF ECOSYSTEM INDICATORS FOR PUGET SOUND

The Puget Sound Partnership's Indicators Action Team

Introduction

In 2007, the Washington State Legislature enacted Engrossed Substitute House Bill 5372 creating the Puget Sound Partnership (PSP) with a mandate to restore the health of Puget Sound by 2020. This mandate was defined according to six goals: 1) A healthy human population supported by a healthy Puget Sound that is not threatened by changes in the ecosystem, 2) A quality of human life that is sustained by a functioning Puget Sound ecosystem, 3) Healthy and sustaining populations of native species in Puget Sound, including a robust food web, 4) A healthy Puget Sound where freshwater, estuary, near shore, marine, and upland habitats are protected, restored, and sustained, 5) An ecosystem that is supported by ground water levels as well as river and stream flow levels sufficient, to sustain people, fish, and wildlife, and the natural functions of the environment, and 6) Fresh and marine waters and sediments of a sufficient quality so that the waters in the region are safe for drinking, swimming, shellfish harvest and consumption, and other human uses and enjoyment, and are not harmful to the native marine mammals, fish, birds, and shellfish of the region.

By design, restoration of the Sound is to be guided by a science-based Action Agenda describing a list of priority activities to be updated over time. In turn, the scientific underpinnings of the Action Agenda would be developed in the Puget Sound Science Update (PSSU), a recurring characterization of environmental and social condition in the Puget Sound Ecoregions. Specifically, the PSSU would describe: 1) the current scientific understanding of physical attributes of Puget Sound, 2) a scientific process for selecting environmental indicators measuring the health of Puget Sound, and 3) guidance on how to establish targets for environmental indicators. Shortly after the PSP was created, the scope of the PSSU was expanded to include a description of the social, human health and human wellbeing of the Puget Sound region and a scientific basis for selecting additional indicators including human health and well-being indicators.

Also known as the Partnership's enabling statute, this state law called for the establishment of ecosystem indicators by July 2008. Consequently, the Partnership attempted to develop a limited set of science-based measurements that accurately reflect the status of the Puget Sound ecosystem. However, by 2010, the Partnership had not yet selected a final set of ecosystem indicators. Thus, in February 2010, the Indicators Action Team (IAT) was formed as part of the newly designed and launched performance management system. This new system would bring the organization into compliance with the statute while responding to the Partnership's leadership, the Governor's Office and the Environmental Protection Agency's leaders who considered performance management a high priority to be implemented.

In March 2010, scientists and other leaders were selected by Partnership staff to form the IAT. Expertise of team members covered the natural and social sciences with members drawn from federal and state agencies and non-governmental organizations. It was most important that the Team include positive, like-minded professionals who would likely collaborate well together and get the job done, on time.

Team members were invited toparticipate in an initial meeting, with other team members added over subsequent meetings based on perceived gaps in expertise. The Team's work was facilitated by the Partnership's Performance Manager and assisted by two students. The IAT was composed of:

- Leonard Bauer, Department of Commerce
- Helen Berry, Department of Natural Resources
- Mary Beth Brown, Puget Sound Partnership
- Rob Duff, Department of Ecology

- Angela Grout, US Environmental Protection Agency
- Ken Currens, Northwest Indian Fisheries
- Phil Levin, National Oceanic and Atmospheric Administration
- Tim Quinn, Department of Fish and Wildlife
- Trina Wellman, Northern Economics, Inc.
- Jacques White, Long Live the Kings
- Bethany Johnson, University of Washington (student)
- Brian Payne, University of Washington (student)
- John Becker, Puget Sound Partnership, Team Facilitator

It was believed that the mix of scientific expertise, organizational affiliation and management wisdom represented by these Puget Sound-based leaders would be just the right combination of influences to support launching the Partnership's new Performance Management efforts.

The IAT was charged by PSP leadership with developing between 12 and 20 environmental indicators by July 2010. The selected indicators eventually became known as the Dashboard of Ecosystem Indicators (the Dashboard). The Dashboard is defined as a relatively small, representative collection of interconnected natural, human and program dimension indicators that reflect both short- and long-term progress for restoring the health of Puget Sound. The Team agreed that an effective Dashboard should:

- provide an ongoing snapshot of the overall health of the Sound
- show the collective impacts of new and ongoing management strategies
- reveal the results for key ecosystem, human and program dimension measurements in advance of State of the Sound reports
- be ecologically important and socially resonant

The Dashboard presented here is primarily composed of status and trends type indicators.[1] The IAT acknowledges that the Dashboard does not represent all of the indicators that may be needed to measure the health of Puget Sound. Instead, the Dashboard's indicators are to serve as high-level, outcome type measures of the health of Puget Sound and of the health and well-being of the people of Puget Sound. Additional indicators will be necessary to evaluate the effectiveness of specific management actions and to assess specific aspects of the natural and human systems involved.

Development of the Dashboard of Ecosystem Indicators for Puget Sound: Standing on the shoulders of previous Puget Sound indicator efforts

The development of the Dashboard in alignment with the critical components of the ecosystem is built upon the foundation of previous indicator work conducted by the PSP and Its predecessor organizations. In particular, the Dashboard uses approaches outlined in the following sources:

- Chapter 1 of the Puget Sound Science Update (PSSU)
- Environmental Indicators for the Puget Sound Partnership: A Regional Effort to Select Provisional Indicators (Phase 1)

[1] Status and trends monitoring can be thought of as broad, integrated and long-term effectiveness monitoring of a wide array of management strategies. More specific, project effectiveness monitoring is needed, however, to assure that successful management actions are propagated as part of a strategy while ineffective ones are discontinued. Likewise when our management actions have unknown and potentially complex consequences, cause and effect monitoring can be used to understand the connection between actions and ecosystem outcomes.

- PSP Action Agenda
- 2009 PSP Technical Memoranda: Identification of Ecosystem Components and Their Indicators and Targets
- Ecosystem Status and Trends, a literature review on human well-being indicators including a ranking of potential indicators using criteria established by the NOAA NW Fisheries Science Center staff (O'Neill, Bravo and Collier, 2008)
- Input from social scientists and stakeholders in the Performance Management/Open Standards process conducted by PSP staff (PSP, 2009)
- Review of human well-being indicators in Part 2b of the PSP Science Update (Mercer et al, 2010)

Outlined below are the logic, principles, and rationale used by the IAT in developing indicators for the Dashboard. Appendix B outlines the specific steps that led to identification of the natural dimension indicators. Details concerning the IAT's selection of the Dashboard's human dimension indicators are shown in Appendix C.

Based on the philosophy of the Open Standards for the Practice of Conservation

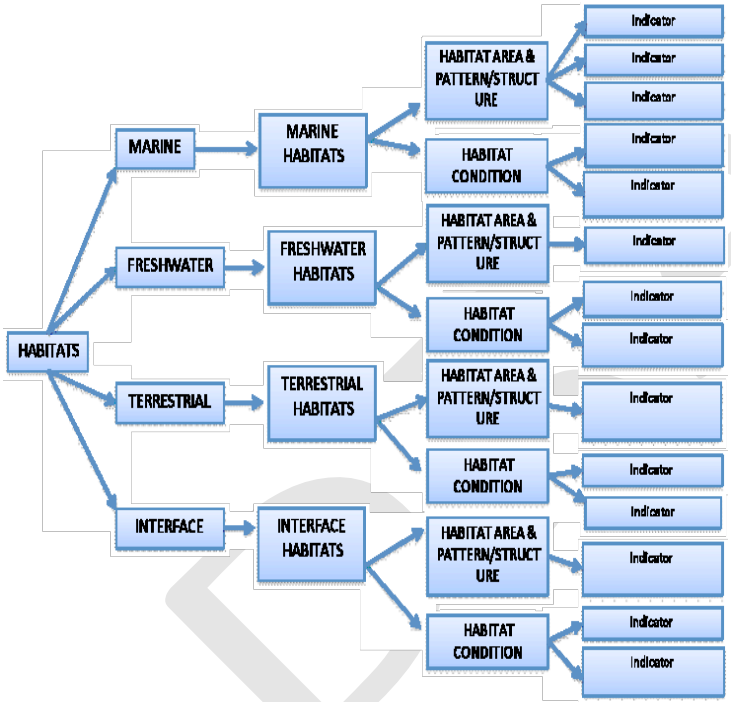

Figure 1. Example of linkage between PSP Goals and indicators as redrawn from the Puget Sound Science Update, Chapter 1

The IAT employed a straightforward approach to organize indicators into logical and meaningful ways in order to assess progress towards policy goals. We used the PSSU Chapter 1 framework, which was derived directly from the implementation of the Open Standards for the Practice of Conservation in Puget Sound. Our framework thus begins with the six Goals of the PSP. We then decomposed those goals into unique ecological Focal Components within specific habitat domains (i.e., marine, freshwater, terrestrial, and interface/ecotone) or as related to human dimensions. Each focal component is characterized by key attributes, which describe fundamental aspects of each focal component. Finally, we map Indicators onto each ecosystem key attribute. We define **indicators** as bio-physical or socio-economic measurements that serve as proxies of the conditions of key attributes of natural and socio-economic systems, whereas **ecosystem attributes** are characteristics that define the structure, composition and function of the ecosystem that are of scientific and/or management importance, but insufficiently specific and/or logistically challenging to measure directly. Thus, indicators provide a practical means to judge changes in ecosystem attributes related to the achievement of management objectives. The framework is illustrated in Figure 1 above for the Habitat goal. Adoption and use of this framework ensured that the IAT kept in mind how Dashboard measures related to PSP goals, focal components and key attributes.

Considering a broad range of diverse indicators

We began populating the framework described above with indicators by first gathering all indicators previously selected for use by the PSP. Chapter 1 of the PSSU compiled a comprehensive list of such indicators including:

- About 250 indicators from "Environmental Indicators for the Puget Sound Partnership: A Regional Effort to Select Provisional Indicators (Phase 1)" that were considered "good," "potential," or "possible future."
- 102 environmental indicators that were listed in the PSP Action Agenda based on a review by the PSP Science Panel.
- 160 indicators from the process specifically guided by the Open Standards for the Practice of Conservation
- 43 indicators from the PSP Technical Memorandum, "Ecosystem Status and Trends," (a subset of these were used in the 2009 State of the Sound report).
- >150 water quantity indicators derived from a literature review of indicators that may track various aspects of the hydrologic flow regime.
- The entire set of indicators was combined and redundant indicators removed, and then organized according to goals, ecosystem components and attributes of our framework.

Considering the specificity and sensitivity of indicators

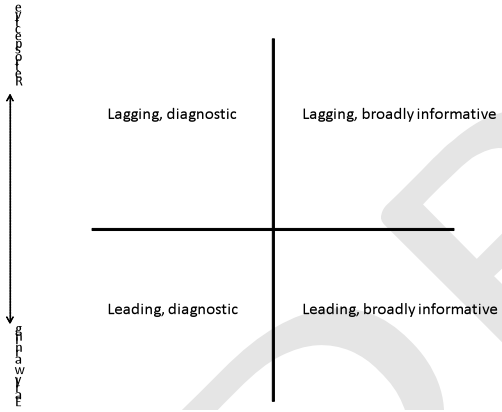

Figure 2. Specificity and sensitivity display of ecosystem indicators

The IAT thought that a useful way to evaluate indicators was to consider in more detail the evaluation criterion "the indicator responds predictably and is sufficiently sensitive to a specific ecosystem attribute." Two of the terms in this criterion, "specific" and "sensitive," can be used to organize indicators according to the type of information they provide about attributes. An indicator's specificity depends on whether it reliably tracks few or many attributes. An indicator that provides information about many attributes is non-specific but broadly informative, while that which serves well as a proxy for fewer attributes can be thought of as diagnostic of changes in specific ecosystem conditions. Another informative axis on which to interpret an indicator is in terms of its sensitivity. An indicator that provides information about impending changes in attributes before they occur is an early warning or "leading" indicator. In contrast, an indicator that reflects changes in attributes only after they have occurred is a retrospective or "lagging" indicator.

The IAT thus considered how highly-ranked, natural dimension indicators mapped along the axes of specificity and sensitivity by roughly plotting them on a graph such as the one shown above.[2] The objective of this exercise was simply to be cognizant of what type of information each indicator would provide, and to avoid selecting too many indicators from a single quadrant. No value judgment was made about individual quadrants (i.e., a leading diagnostic indicator was not considered any better than lagging, broadly informative indicator). Based on this

[2] A detailed description of the indicator evaluation process can be found in Chapter 1a of the Puget Sound Science Update. Appendix B outlines how the IAT applied the PSSU framework to the Dashboard Indicators.

four quadrants approach, three Portfolios of potential indicators were assembled by the IAT. This helped the Team and other PSP groups consider various options in selecting natural dimension indicators for the Dashboard.

In assembling the natural dimension indicators for the Dashboard, the team explicitly viewed this as the creation of a portfolio of complementary indicators. The objective was not to represent every ecosystem attribute, every process or every species in the Sound, but rather to assemble a scientifically credible portfolio of indicators that would provide a breadth of information about different ecosystem components over different temporal and spatial scales.

Using all available information, the IAT developed three alternative Dashboard indicator portfolios (see Appendix A). Each portfolio is scientifically robust and meaningful, and taken as a whole can be considered to be the "vital signs" of Puget Sound in a similar way that blood pressure, heart rate, and temperature may be seen as the vital signs of human health. The Team chose Portfolio A, which represents the Team's consensus as the best indicators for the Dashboard. Portfolios B and C are equally scientifically credible, but emphasize slightly different parts of the ecosystem.

Table 1. Recommended Dashboard of Ecosystem Indicators for Puget Sound

Natural Dimension	Human Dimension	Program Dimension
Marine Water Quality Index	Sound Behavior Index (under construction)	Funding for Action Agenda
Freshwater Quality Index	Puget Sound Quality of Life Index (under construction)	Percent of Action Agenda Items Addressed
Stream Flows Below Critical Levels	Tribal/Non-Tribal Commercial Harvest	
Wild Chinook Salmon	Swimming Beaches	
Orcas/ South Resident Killer Whales	Recreational Fishing Permit Sales	
Pacific Herring	Shellfish Beds Restored	
Birds		
Shoreline Armoring		
Eelgrass		
Toxics in Fish		
Toxics in Sediments		
Land Use/Land Cover		

NOTE: Table 1 represents the Dashboard of Ecosystem Indicators for Puget Sound but is not identical to the original indicators selected as Portfolio A by the IAT. The differences reflect changes following external input/comments received, further discussion amongst the IAT and guidance from PSP.

There is nothing magical about these three portfolios. They balance a wide variety of indicators across the natural, human and program dimensions of the Dashboard, the five Action Agenda goals and have degrees of sensitivity and selectivity. Our aim was to get similar balance among the three portfolios across the two axes of sensitivity and selectivity. Other criteria not considered could be important to choosing one indicator over its alternative. For example, upon careful examination of logistical issues associated with sampling, we may find that it is twice as expensive to collect data on one indicator versus its alternatives. It will be wise to retain some flexibility in choosing and improving specific indicators for the same attribute over time until feasibility assessments (sampling plans) can be completed and any risk associated with lagging indicators can be assessed.

No explicit effort was made to rank indicators or portfolios by their social resonance or marketing potential. The IAT felt that this was a judgment best left to others. Indeed, the Team strongly urges a careful and rigorous examination of the social value of these portfolios over time. We emphasize that these portfolios are built on the foundation of all the PSP indicator efforts from the past as well as the work by PSP's precursor organizations.

Review and modification of proposed indicators

The process for choosing these 20 indicators was, by necessity, a blend of scientific evaluation and expert opinion. It was based on the understanding that the IAT needed to limit the number of indicators they could consider to represent status of the ecosystem, how the Dashboard Indicators would be used and interpreted, and a necessity to complete this work by July 2010.

Although the IAT attempted to separate scientific from social or political criteria, the selection of indicators was influenced by the Team's perspective of what would be socially resonant. For example, out of many potentially informative indicators, we chose wild Chinook salmon and orcas because we believe them to be iconic species in Puget Sound. Likewise, although the IAT recommended jellyfish, the Team later replaced jellyfish with herring. Although jellyfish are a demonstrably stronger ecosystem health indicator than herring, herring was ultimately selected based on the presence of historical data on herring as well as comments received during meetings of the Science Panel, Ecosystem Coordination Board and Leadership Council. Thus, it is important to acknowledge that the proposed indicators were affected by the opinions and perceptions of the IAT, other PSP leaders and a variety of ad hoc commenters. Importantly, input external to the PSP was not broadly or systematically solicited, and as a result may not be generally representative of scientists, managers or citizens in the region. It is possible that a different group of individuals serving on the Indicators Action Team would have chosen a different group of indicators or may even have failed to complete this work within the timeframe required.

Selection of Human Health indicators

In keeping with the goals of the Action Agenda, two human health indicators were chosen by the IAT to include:

- Swimming beaches
- Shellfish beds restored (an established indicator of success with the Environmental Protection Agency)

Selection of Human Well-being indicators

Plummer and Schneidler, 2009 and Chapter 2b (in draft) of the PSSU guided the compilation of a comprehensive list of human wellbeing indicators. Human wellbeing indicators were chosen for the Dashboard based on representation in one or more of each of the following six focal components as provided in the Open Standards process.

1. Regional makeup (including demographics, economic, water use and transportation trends).
2. Social capital (e.g. environmental stewardship, citizen scientists)
3. Impact of recovery strategies on marine and land based natural resource industries (unintended consequences of Action Agenda implementation)
4. Ecosystem services which provide benefits to people
5. Behavioral change of public as awareness increases
6. Existence value of the ecosystem (including aesthetics and willingness to pay to assure the continued survival of individual species or general health of the ecosystem)

This list of strategic outcomes has appeared repeatedly throughout the Partnership's work on human well-being indicators. For the purposes of our 2010 Dashboard, indicators with current robust data sources were selected for four of the six focal components:

- Regional makeup – *Puget Sound Regional Council's Trends Index*
- Impact of recovery strategies on marine and land based natural resource industries – *Commercial Fisheries Harvest (Tribal and Non-Tribal; annual wild harvest in pounds)*
- Ecosystem services which provide benefits to people – *Participation in recreational fish, shellfish and hunting harvest (number of permits issued)*
- Behavioral change of public as awareness increases – *Personal vehicle miles traveled*

Again, as indicated above, ad hoc comments and perceptions led to changes in the final list of human wellbeing indicators. It was decided that the regional makeup and behavioral change focal components required the generation of two new indices of "Puget Sound Quality of Life" and "Sound Behavior" with respective data needs. These two indicators replaced the Trends Index and Personal vehicle miles traveled and are currently under development by PSP staff.

Selection of Program indicators

Finally, two program indicators were selected to provide an Action Agenda accountability focus on the Dashboard, as well:

- Funding for Action Agenda
- Percent of Action Agenda items addressed

Next Steps

Two key elements of a rigorous evaluation of the Dashboard indicators may still need to occur, and may or may not lead to a different suite of Dashboard indicators. First, the social resonance of these indicators needs to be tested using methods developed by social scientists. This should routinely be accomplished as we move forward. The Indicators Action Team does not represent a cross section of the public, and thus is incapable of rendering unbiased judgment on the social value of the indicators. Careful research will reveal how and why citizens use the Dashboard, and may influence which indicators are determined to be most useful over time.

The development of the Dashboard of Ecosystem Indicators has been a performance management-, policy- and science-driven process, and although external peer review is fundamental to the scientific process, the Dashboard was not subjected to such a formal review. In addition, the Dashboard has not been widely available for scrutiny by the Puget Sound scientific community. Ideally, this work would have been more broadly shared

throughout the scientific community before the Dashboard was launched, but time did not allow prior to the Dashboard's launching. This will occur in the future as part of the routine review and improvement of the Dashboard indicators going forward. Additionally, enlisting the input and support of the community at large is crucial to the Partnership's success.

Launching the Dashboard is simply the beginning of selecting, evaluating and improving ecosystem indicators for Puget Sound. In addition to the steps outlined above (which will likely help to improve the Dashboard), other indicators or suites of indicators, in addition to the Dashboard indicators will need to be chosen. While the Dashboard should provide a sense of the overall health of the Sound, in general, the information it provides is not specific enough to most fully guide management actions. Further, more specific, diagnostic indicators will be required. For instance, a decline in the number of salmon may signal a problem, but that fact in itself does not reveal the specific nature of the problem. As a result, a number of more specific indicators of habitat, water quantity, water quality and food web processes may be needed to guide the appropriate management response.

Similarly, indicators of ecosystem drivers and pressures may need to be more fully developed. Although the Dashboard does include some indicators related to ecosystem threats, the Dashboard was not developed specifically with this sort of approach in mind. The Indicators Action Team discussed the possibility of future indicator development efforts possibly focusing on the key threats to the ecosystem (threat reduction indicators).

Finally, a major effort to establish targets for key indicators is just beginning as called for in the Partnership's enabling legislation. A new Target Setting process is being developed to structure and standardize the Partnership's target setting process over time.